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Geochemistry, geochronology and Sr–Nd–Pb–Hf isotopic compositions of Middle to Late Jurassic syenite–granodiorites–dacite in South China: Petrogenesis and tectonic implications

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ABSTRACT

In situ zircon U–Pb ages and Hf isotope data, major and trace elements and Sr–Nd–Pb isotopic compositions are reported for coeval syenite–granodiorites–dacite association in South China. The shoshonitic syenites are characterized by high K_2O contents (5.9–6.1 wt.%) and K_2O/Na_2O ratios (1.1–1.2), negative Eu anomalies ($Eu/Eu^* =$ 0.65 to 0.77), enrichments of Rb, K, Nb, Ta, Zr and Hf, but depletion of Sr, P and Ti. The adakitic granodiorite and granodiorite porphyry intrusions are characterized by high Al_2O_3 contents (15.0–16.8 wt.%), enrichment in light rare earth elements (LREEs), strongly fractionated LREEs (light rare earth elements) to HREEs (heavy rare earth elements), high Sr (438–629 ppm), Sr/Y (29.2–53.6), and low Y (11.7–16.8 ppm) and HREE contents (e.g., Yb = 1.29–1.64 ppm). The calc-alkaline dacites are characterized by LREE enrichment, absence of negative Eu anomalies, and enrichment of LILEs such as Rb, Ba, Th, U and Pb, and depletion of HFSEs such as Nb, Ta, P and Ti. Geochemical and Sr–Nd–Hf isotopic compositions of the syenites suggest that the shoshonitic magmas were differentiated from parental shoshonitic melts by fractional crystallization of olivine, clinopyroxene and feldspar. The parent magmas may have originated from partial melting of the lithospheric mantle with small amount contribution from crustal materials. The adakitic granodiorite and granodiorite porphyry have Sr–Nd–Pb isotopic compositions that are comparable to that of the mafic lower crust. They have low Mg# and MgO, Ni and Cr contents, abundant inherited zircons, low $\varepsilon_{Nd}(t)$ and $\varepsilon_{Hf}(t)$ values as well as old whole-rock Nd and zircon Hf model ages. These granodiorites were likely generated by partial melting of Triassic underplated mafic lower crust. The Hf isotopic compositions of the dacites are relatively more depleted than the Cathaysia enriched mantle, suggesting those magmas were derived from the partial melting of subduction-modified mantle sources. The coeval shoshonitic, high-K calc-alkaline and calc-alkaline rocks in Middle to Late Jurassic appear to be associated with an Andean-type subduction. This subduction could have resulted in the upwelling of the asthenosphere beneath the Cathaysia Block, which induced partial melting of the mantle as well as the mafic lower crust, and formed an arc regime in the coastal South China during Middle to Late Jurassic.

1. Introduction

The South China is characterized by large-scale emplacement of igneous rocks as a result of west-dipping subduction of the paleo-Pacific plate in the Mesozoic (Jahn et al., 1990, 1996; Zhou and Li, 2000; Li and Li, 2007; Zhang et al., 2013). During the Jurassic (Early Yanshanian), extensive granitic magmatisms are distributed in the inland discretely in the NE–SW direction and parallel to the present coastline, forming a 600-km-wide intracontinental orogen and post-orogenic magmatic belt in South China (Fig. 1; Li et al., 2003; Zhou et al., 2006; Li et al., 2007a,b; Huang et al., 2011). Less abundant Jurassic syenites, gabbros and basalts occurred on the two sides of the Chenzhou-Linwu Fault within the South China (Fig. 1; Xie et al., 2006; Y.J. Wang et al., 2008, 2013), displaying two arrays, oblique and parallel to the coastal lines, providing useful estimate and constraint of the source characteristics of the Jurassic asthenospheric and lithospheric mantle beneath the South China Block (Wang et al., 2003; Xie et al., 2006; Y.J. Wang et al., 2008; Jiang et al., 2009; Y.J. Wang et al., 2013).

Origin and evolution of felsic rocks attracted international interests because they carry the information on the tectonic evolution associated

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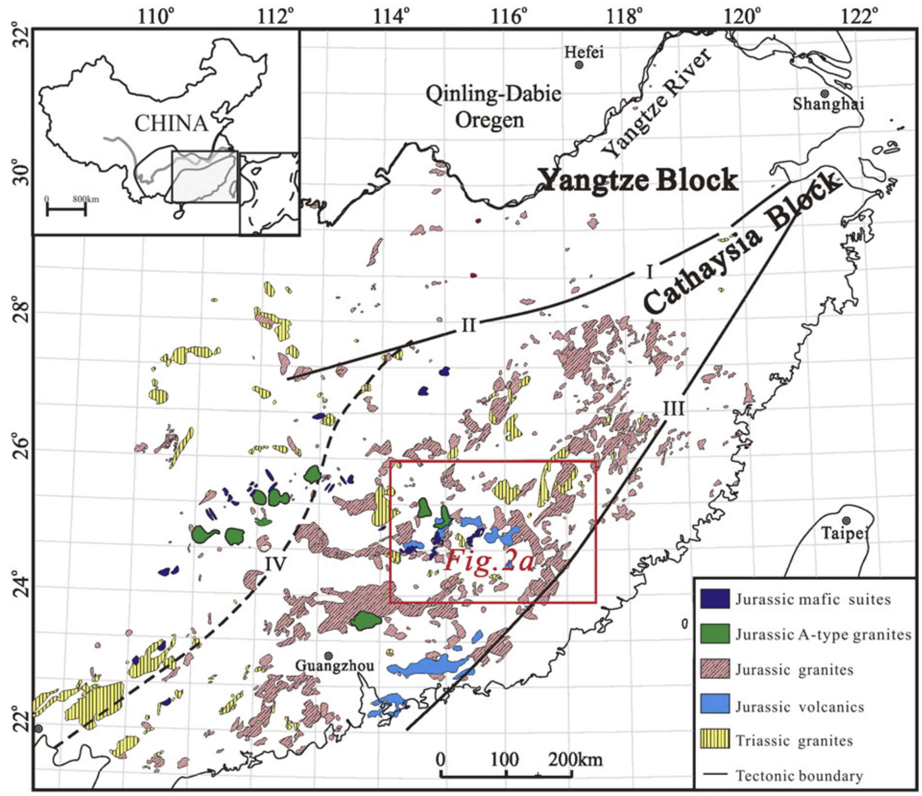

Fig. 1. Schematic geological map of South China showing the distribution of Triassic and Jurassic granitoid and volcanic rocks, modified after Chen et al. (2008), Guo et al. (2012), Li and Li (2007), and Zhou et al. (2006). I—Jiangshan–Shaoxing fault; II—Pingxiang–Yushan fault; III—Zhenghe–Dapu fault; IV—Chenzhou–Linwu fault.

with economically significant mineralization, especially in South China (e.g., Li, 2000; Zhou and Li, 2000; Li and Li, 2007; J.H. Li et al., 2014; X.H. Li et al., 2014). However, the origins of I-type granitoids remain subjects of debate and disagreement (Roberts and Clemens, 1993; Liégeois et al., 1998; Huang et al., 2013). Models for the generation of the I-type granitoids include reworking of sedimentary materials by mantle-derived magmas (Kemp et al., 2007), crystallization–differentiation of basaltic parents (Macpherson et al., 2006), direct partial melting of hydrous medium-to-high-K mafic to intermediate meta-igneous rocks (Roberts and Clemens, 1993), mixing of mantle-derived magmas with crustal-derived materials (Dickinson, 1975; Huang et al., 2013), and assimilation of sialic rocks into differentiating basaltic magmas (DePaolo, 1981). By contrast, partial melting of thickened lower crust without any significant contribution of mantle components (Ma et al., 2013) are also contributed to generate I-type granitoids. Subduction in active continental margins or lithospheric extension in post-collisional/post-orogenic settings (Roberts and Clemens, 1993) have been proposed as the two main driving mechanisms for the petrogenetic and tectonic models resulting in such rocks vary accordingly (Huang et al., 2013). However, few studies involved the nature of granites, and few successful cases were well implemented to identify the contribution of the older magmas to continental crust growth and their tectonic regime so far. Particularly, many of the Mesozoic granitoids are highly evolved and significant compositional similarity exists among granitoids of temporally different events in South China (e.g., Li et al., 2007a, b), making it difficult to constraint their origins. Based on the mantle source, the petrogenesis of syenites involves complex and varied processes in different tectonic settings (e.g., Lan et al., 2011), including partial melting of metasomatized/enriched mantle, differentiation of alkaline basalt magma, and magma mixing of lower crust-derived granitic magmas with mantle-derived silica-undersaturated alkaline mafic magmas. However, depleted asthenosphere are thought to play a crucial role for generating syenites, a process considered as essential for the origin of syenitic compositions in South China (e.g., He et al., 2010).

South China forms a basin-range type province related to the geodynamics of Late Mesozoic tectonism and granitic magmatism with basin formation due to extensional tectonics in a back-arc setting associated with a subduction of the paleo-Pacific plate (Gilder et al., 1991; Li, 2000; Zhou and Li, 2000; Zhou et al., 2006; Li and Li, 2007; Meng et al., 2012). Two major driving mechanisms for the genesis of Late Mesozoic magmatism have been proposed, namely, the extension-induced deep crustal melting and the underplating of mantle derived basaltic melts (Xu et al., 1999; Li, 2000; Zhou and Li, 2000; Zhou et al., 2006; Liu et al., 2013). However, considerable uncertainties and controversies still remain such as crust–mantle interaction models and the nature of the magma sources, the enriched lithospheric mantle evolution and the role of depleted asthenospheric mantle, which lead to different petrogenetic models of Late Mesozoic igneous rocks in SE China (Xu et al., 1999; Dong et al., 2006; He and Xu, 2012). The most widely accepted model interpreted these magmatic events to be the result of subduction of the paleo-Pacific plate in various ways, including normal subduction (Jahn et al., 1990), subduction with changing subduction angles (Zhou and Li, 2000), and a flat-slab subduction followed by a retreat and foundering of the subducted slab (Li and Li, 2007). Although many researchers have discussed the tectonic regime that controlled the Mesozoic magmatism in SE China (Yang et al., 1999; Li, 2000; Zhou and Li, 2000; Dong et al., 2006; Chen et al., 2008; Li et al., 2009a), the magmatic evolution related to the subduction of the paleo-Pacific plate and the temporal and spatial variations within the Late Mesozoic magmatic evolution and the magma sources are still controversial issues.

Coeval felsic and syenitic rocks are distributed in adjacent domains, apparently controlled by a contemporaneous tectono-magmatic evolution event. Previous studies preferred to focus on the complexes within a limited region, showing various emplacement ages as a result of multistage magma activities. Taking an individual complex suite as a research